ONTARIO WATER RESOURCES COMMISSION

REPORT on WATER QUALITY in WESLEMKOON LAKE 1971

RECREATIONAL LAKES PROGRAM

BBCR

THE ONTARIO WATER RESOURCES COMMISSION

REPORT ON WATER QUALITY

IN

WESLEMKOON LAKE

1971

GENERAL TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

A study to evaluate the status of water quality in Weslemkoon Lake was carried out during the summer of 1971.

Weslemkoon Lake lies within the Canadian Shield north of the Frontenac Axis. The area is characterized by rolling hills, poor local drainage and shallow overburden covering crystalline bedrock. Most of the shoreline is quite steep with frequent rock outcroppings. Both the topography and the shallow overburden can be considered unsuitable for the installation of septic tank systems.

Thermal stratification was observed in Weslemkoon Lake during all surveys. Oxygen concentrations in the bottom waters decreased slightly between the surveys. Free carbon dioxide concentrations were higher in the bottom waters than in the surface waters.

The chemical water quality was characteristic of soft-water Precambrian lakes. The use of detergents containing phosphorus is unnecessary in such soft waters and should be avoided by area residents. In July, the level of nutrient enrichment was found to be higher than during the August and October surveys. This may have resulted from the flushout of domestic wastewaters into the lake during the spring snow-melt and subsequent wet weather periods.

Chlorophyll a concentrations were low, reflecting the low productive capacity or oligotrophic status of the lake. In contrast diatom sediment analyses indicate the trophic status of the lake is oligotrophic to mestrophic in character.

The July survey showed great increases in bacterial numbers following the rainfalls with Total Coliforms (TC), Fecal Coliforms (FC) and Fecal Streptococci (FS) exceeding the OWRC criteria for recreational use at several stations. The high bacterial counts, especially FC, are indicative of domestic wastes gaining access to the lake

The lake had good bacteriological water quality during the August survey, but during the October survey the total coliform levels exceeded the OWRC criteria for total body contact recreational use. The FC and FS levels in October were very low indicating that the high TC counts were made up primarily of soil bacteria.

No surface water is considered potable without prior treatment including disinfection, however, particular attention should be given to drinking water taken from Weslemkoon Lake following rainfall.

In view of the observed bacterial contamination and nutrient enrichment of the lake which were suspected of originating from private waste disposal systems, every effort should be made to correct existing systems to ensure that direct flow or leachate from these systems or other potential sources of pollution do not gain access to the lake.

INTRODUCTION

Maintenance of good water quality in recreational lakes in the Province of Ontario is of vital concern to the Ontario Water Resources Commission, The Ontario Department of the Environment and other governmental agencies involved in tourism and the control and management of shoreline development of cottages and resorts. In 1970 an interdepartmental program was established to survey a number of recreational lakes in order to detect and correct sources of water pollution and ensure that our lakes would be well managed to protect water quality. The Ontario Department of Health, whose jurisdiction in this program was transferred to the Department of the Environment in December 1971, would carry out on-shore inspection and correction of faulty private waste disposal systems, whereas the Ontario Water Resources Commission would evaluate the existing water quality of the respective lakes. A record of the present status of the private waste disposal systems and the lake water quality would also be documented for comparative use in any future studies.

Recreational lakes are subjected to two major types of water quality impairment; bacteriological contamination and excessive growths of algae and aquatic weeds (eutrophication). The two problems may result from a common source of wastes but the consequences of each are quite different. Bacteriological contamination by raw or inadequately treated sewage poses an immediate public health hazard if the water is used for bathing. In order for this to occur, raw wastes or septic tank effluents must gain entry to the lake although it may not be obvious upon visual inspection of the site. It must be noted that no surface water is considered safe for human consumption without prior treatment including disinfection. The algae and weed problems which have come into prominence in recent years are caused by plant nutrients being added to the lake. Excessive algae and weed growths impair aesthetic values and recreational use of a lake but seledom pose a health hazard. There are nutrient sources other than sewage wastes which do not create serious bacterial hazards but do support nuisance plant growths, such as agricultural fertilizer losses and normal nutrient runoff from forest and field.

In order to carry out its responsibility of evaluating the status of water quality in recreational lakes, the Ontario Water Resources Commission undertook a study on Weslemkoon Lake in the summer of 1971. Three surveys were conducted; an early summer survey from July 8 to 12, a late summer survey from August 26 to 30 and a fall survey from October 2 to 6 inclusive. These studies included the assessment of bacteriological, physical, chemical and biological conditions of the lake with stress being placed on the bacteriological and nutrient enrichment problems.

Sampling surveys were conducted on an intensive basis (sampling each day for a minimum of five days) which is mandatory for a reliable assessment of bacteriological conditions.

In addition to the results obtained from these studies, information from other governmental agencies has been incorporated in this report which is the Ontario Water Resources Commission's contribution to the Interdepartmental Task Force Report which will deal with the overall cottage pollution control progrm in Ontario.

AREA DESCRIPTION

Geography and Topography

Weslemkoon Lake is located in Effingham Township, County of Lennox and Addington, and is approximately 35 kilometers (22 miles) east of Bancroft. The lake lies within the Canadian Shield north of the Frontenac Axis and the area is characterized by rolling hills, poor local drainage, crystalline bedrock and a shallow overburden with the exception of some localized glacial deposits. The prevalent overburden in this area is a thin layer of humus although there are some areas of sandy loam. Most of the shoreline is quite steep with frequent outcroppings of rock. The surrounding area has a moderate to heavy forest cover of coniferous and deciduous trees. Generally, the soil depth is less than the five feet required by the Department of the Environment for the installation of a septic tank system.

In 1952 the Department of Lands and Forests' control dam at the northwest end of Weslemkoon Lake was reconstructed and the water level was allowed to rise 2 meters (6 feet). As a result of this flooding marshy areas were created at the northern end of the lake, the southern inlet, and at most tributary entrances. With the exception of these areas, the aquatic vegetation is quite sparse. The lake has a water surface area of 20 square kilometers (7.5 square miles), a shoreline of 89 kilometers (55 miles) and a maximum depth of 55 meters (180 feet).

Climate Range

The area has a mean daily temperature of $-10^{\circ}C$ ($14^{\circ}F$) in January and a mean daily temperature of $19^{\circ}C$ ($66^{\circ}F$) in July. The mean annual precipitation is 71 to 102 centimeters (28 to 40 inches) including 203 centimeters (80 inches) of snow. According to meteorological reports, the area enjoys about 295 days with no measurable precipitation. The winter with its abundance of snow early in the season provides for participation in most winter sports.

Water Movement

The Weslemkoon Lake drainage basin, 310 square kilometers (120 square miles) in area, forms the headwaters of the Little Mississippi River which flows via the York River into the Madawaska River system (Figure 1). As part of the Ottawa River Terminal Drainage Basin, the Madawaska River contributes approximately 5% of the Ottawa River's mean annual flow. The Weslemkoon drainage basin is roughly circular with water rising to an elevation of 396 meters (1300 feet) above mean sea level (m.s.l.) and flows via a system of small lakes and streams to Weslemkoon Lake which has an elevation of 318 meters (1,044 feet) above m.s.l.

There is very little fluctuation in the lake level due to the control dam on the Little Mississippi River. The major tributaries are Cotter Lake which drains Ashby and Barker Lakes via Ashby Creek, Effingham Lake and Fraser, Coburn and Aide creeks. The only major outlet of the lake is the Little Mississippi River which begins at the Lands and Forests' control dam in the northwest corner.

Shoreline Development

Road access and package sales of crown land have helped to determine the pattern of development of the approximately 300 cottages on Weslemkoon Lake. The north road provides automotive access to some 45 cottages and two marinas whereas the south road serves 25 cottages and one marina. The remaining 230 cottages, of which 90 are situated on islands, are accessible only by boat. The package land sales have resulted in small communities of cottages being formed such as those found along the south shore of West Bay and around the shore of Regina Bay. The cottages are widely scattered along the shoreline.

Water Usage

Most cottaters use the lake as their source of domestic water supply. Recreational uses of the lake include boating, swimming and angling. The lake sustains a strong lake trout fishery as well as a largemouth and smallmouth bass fishery.

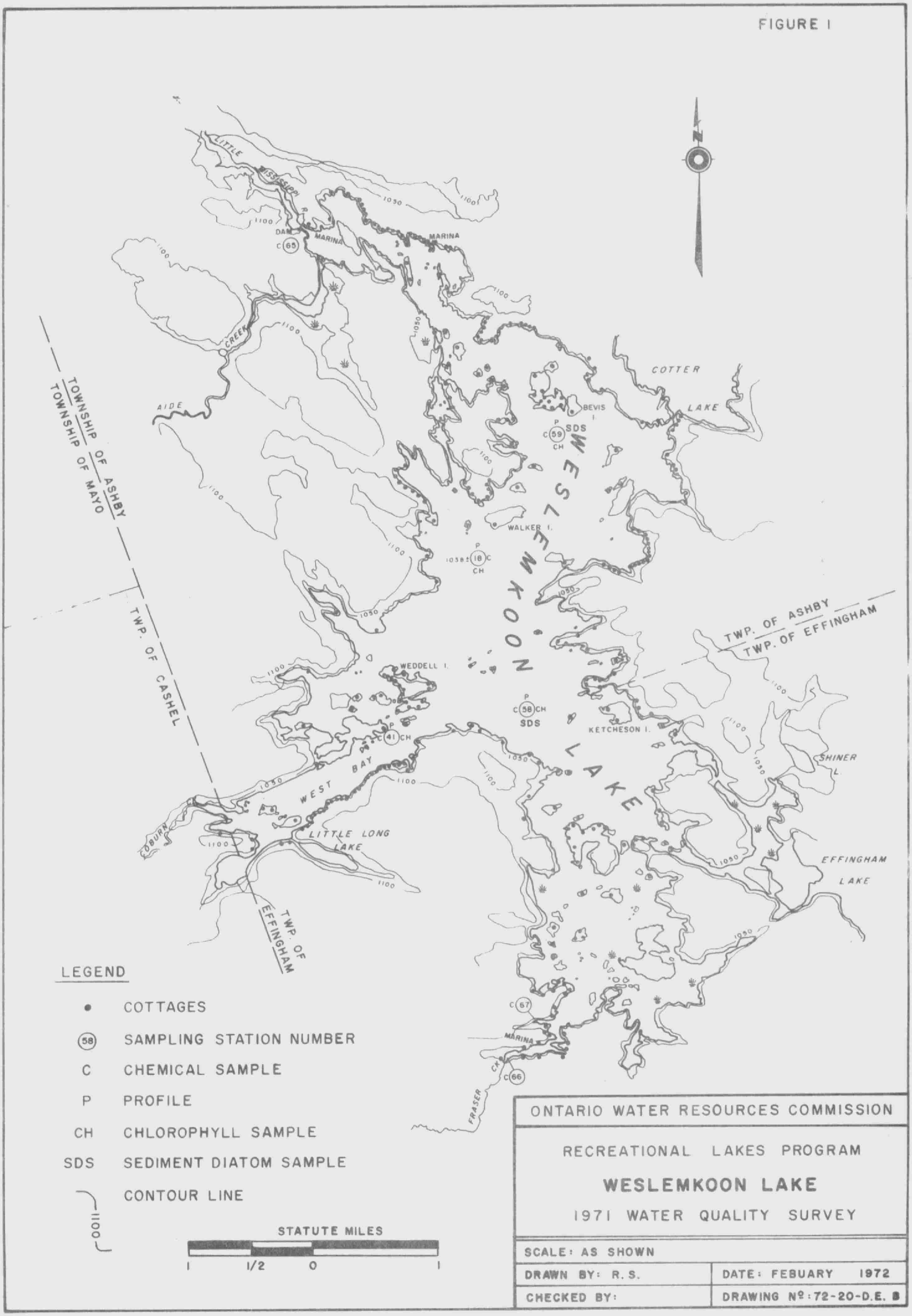


FIGURE I
WESLEMKOON LAKE
LITTLE MISSISSIPPI R.
DAM
MARINA
CREEK
AIDE
TOWNSHIP OF ASHBY
TOWNSHIP OF MAYO
TWP. OF CASHEL
TWP. OF ASHBY
TWP. OF EFFINGHAM
TWP. OF EFFINGHAM
COTTER LAKE
BEVIS I.
WALKER I.
WEDDELL I.
KETCHESON I.
SHINER L.
EFFINGHAM LAKE
WEST BAY
LITTLE LONG LAKE
OBURN
FRASER CK.
1100
1050
SDS
LEGEND
COTTAGES
SAMPLING STATION NUMBER
C CHEMICAL SAMPLE
P PROFILE
CH CHLOROPHYLL SAMPLE
SDS SEDIMENT DIATOM SAMPLE
CONTOUR LINE
STATUTE MILES
1 1/2 0 1
ONTARIO WATER RESOURCES COMMISSION
RECREATIONAL LAKES PROGRAM
WESLEMKOON LAKE
1971 WATER QUALITY SURVEY
SCALE: AS SHOWN
DRAWN BY: R. S.
DATE: FEBUARY 1972
CHECKED BY:
DRAWING Nº: 72-20-D.E. B

There are no direct discharges of wastes into Weslemkoon Lake from communal or municipal sewage treatment facilities. There does not appear to be any pollution from the operation of existing municipal solid waste disposal sites.

FIELD AND LABORATORY METHODS

Physical, Chemical and Biological Field Methods

Physical, chemical and biological water quality surveys were conducted from July 8 to 12, from August 26 to 30 and from October 2 to 6. Three near-shore stations (65, 66 and 67) and four mid-lake stations (18, 41, 58 and 59) were selected for chemical and biological sampling. The near-shore stations were close to inlets and outlets.

Dissolved oxygen and temperature profiles were determined daily in the field using a combination dissolved oxygen-telethermometer unit. Total alkalinity and free carbon dioxide were measured daily titrimetrically and pH was measured with a portable pH meter. Daily chlorophyll samples were collected in a 32-ounce bottle, at each station, utilizing a composite sampler lowered through the euphotic zone (2X Secchi disc) and immediately preserved with 10-15 drops of 2% $MgCO_3$.

Once per survey a 32 ounce sample for hardness, alkalinity, chloride, total phosphorus, total Kjeldahl nitrogen, iron and conductivity was collected at all mid-lake stations as well as at the major inlets and outlets. The mid-lake stations were sampled using a composite sampler through the euphotic zone. At inlets and outlets, samples were collected from 1 meter of depth using a Kemmerer sampler.

At each mid-lake station one sample for total phosphorus, total Kjeldahl nitrogen and iron was obtained by means of a Kemmerer sampler from a depth of 1 meter above the bottom on August 30. Three sediment cores for diatom frustule examination were collected during the winter at Stations 58 and 59. From the surface of each sediment core three subsamples were removed for laboratory enumeration to species.

Physical, Chemical and Biological Laboratory Methods

All analyses were carried out using routine OWRC methods based on Standard Methods 13th Edition.

Iron was measured after the sample had been digested with acid to dissolve all forms of iron present.

Kjeldahl nitrogen and total phosphorus were determined after the sample was digested with acid an oxidizing agent to destroy organic matter.

For chlorophyll determinations, 1 liter samples were filtered through a 1.2 μ membrane filter which was then extracted with 90% acetone for 24 hours. Absorbance of the extract was determined at wavelengths 600 to 750 mμ using a Unicam SP1800 ultra violet spectrophotometer. The concentrations of chlorophyll a were calculated using the equation given by Richards and Thompson (1952).

Bacteriological Field and Laboratory Methods

Five day intensive bacteriological surveys were completed on Weslemkoon Lake during July, August and October. Fifty-seven stations in July, sixty-two stations in August and forty-five stations in October were sampled each day one meter below the surface using sterile, autoclavable polycarbonate 250 ml bottles. Additional samples were collected at stations 7, 16, 18, 27 and 49 in July and August and at stations 18, 27 and 49 in October (Figure 6) one meter above the bottom using a modified "piggy-back" sampler and sterile 237 ml evacuated rubber syringes. All samples were stored on ice and delivered to the mobile laboratory within two to six hours and analyzed for total coliforms, fecal coliforms and fecal streptococcus using the membrane filtration technique (MF) (Standard Methods 13th Edition) except that m-Endo Agar Les (Difco) was used for total coliform and MacConkey membrane broth (Oxoid) was used for fecal coliform determinations. The total coliforms (TC) fecal coliforms (FC) and fecal streptococcus (FS) were used as "indicators" of fecal pollution.

These "indicators" are the normal flora of the large intestine, and are present in large numbers in the feces of man and animals. When water is polluted with fecal material, there is a potential danger that pathogens or disease causing micro-organisms may also be present.

The coliform group is defined, according to Standard Methods 13th Edition, as "all of the aerobic and facultative anaerobic, gram-negative, non-sporeforming rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35^{o}C" and, or "all organisms which produce a colony with a golden green metallic sheen within 24 hours of incubation" using the MF technique. This definition includes, in addition to the intestinal forms of the Escherichia coli group, closely related bacteria of the genera Citrobacter and Enterobacter. The Enterobacter - Citrobacter groups are common in soil, but are also recovered in feces in small numbers and their presence in water may indicate soil runoff or, more important, less recent fecal pollution since these organisms tend to survive longer in water than do members of the Esherichia group, and even to multiply when suitable environmental conditions exist. A more specific test for coliforms of intestinal origin is the fecal coliform test, with incubation of the organisms at 44.5^{o}C. Though by no means completely selective for Escherichia coli, this test has proved useful as an indicator of recent fecal pollution.

Fecal streptococci (or enterococci) are also valuable indicators of recent fecal pollution. These organisms are large, ovoid gram-positive bacteria, occurring in chains. They are normal inhabitants of the large intestine of man and animals, and they generally do not multiply outside the body. In waters polluted with fecal material, fecal streptococci are usually found along with coliform bacteria, but in smaller numbers, although in some waters they may be found alone. Their presence, along with coliforms, indicates that at least a portion of the coliforms in the sample are of fecal origin. All the bacteriological data collected in these surveys has been summarized by statistical methods to form a concise outline of the bacterial concentrations.

Bacteriological Statistical Methods

The results from all the analyses were organized as replicates representing the stations during the survey period. All data were transformed to logarithms (base 10) and all further analyses were done using these transformed data. A geometric mean (the antiloqarithm of the average of the logarithm) was calculated on each station and for each parameter. The validity of the analyses of variance program (ANOVA-CRE; Burger, 1972), was based on the assumptions that the variances of all the stations were similar (Bartlett's test of Homogeneity) and that the data were normally distributed. Both of these assumptions were checked on Weslemkoon Lake. If the Bartlett's test was found to be significant, the stations which possessed the significantly different variances were removed from that group, then the analysis of variance (F-test; Sokal, 1969) was calculated in all the stations. If the F was significant, then the multiple-t test was used to help determine the stations which should be deleted from the overall group to yield a homogeneous group of stations. The withdrawn stations were regrouped with respect to geographic proximity and similar means. The calculations on all groups were repeated using the analysis of variance program until each discrete group was homogeneous. The homogeneous groups that were geographically isolated were compared by means of the Student-t test (using the log GM and S.E.) which indicated the statistical difference between these groups. The Student-t test was also used to compare the grouped bacteriological data from three surveys.

DISCUSSION OF RESULTS

Temperature and Dissolved Oxygen

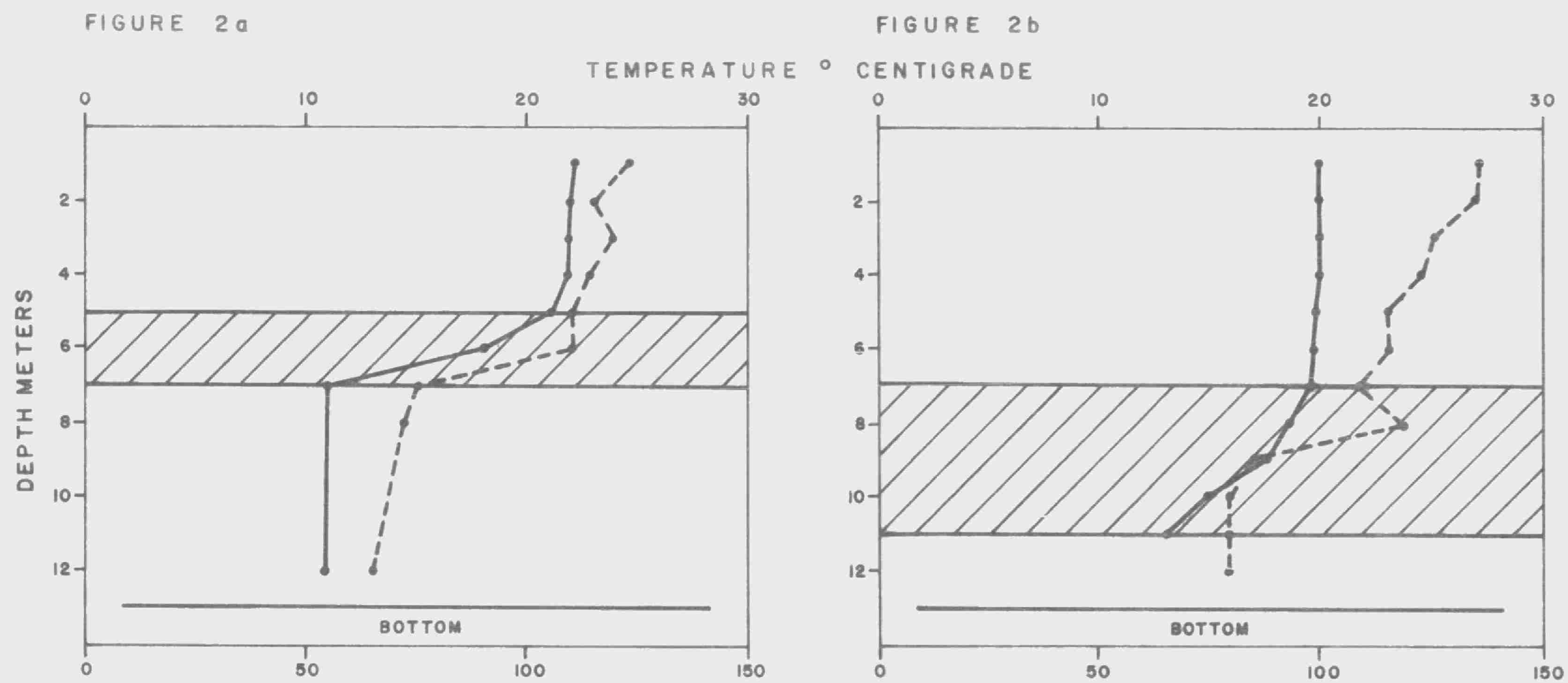
During the July survey, a well-defined thermocline was observed between 5 and 7m (Figure 2a) and between 4 and 6m (Figure 3a) An oxygen reduction was apparent through the metalimnion with no severe oxygen depletion being evident in the bottom waters.

The thermocline was lower in August than in July, being located between the 7 and 11m depths (Figure 2b). A small metalimnetic increase of oxygen was apparent at Station 41 (Figure 2b) indicating an increase in photosynthetic activity at that depth.

In October, the thermocline at both deep-water sampling sites was between 9 and 14 meters of depth (Figures 2c & 3b). This downward shift was in keeping with the expected seasonal changes characteristic of small inland lakes. A severe hypolimnetic oxygen decrease was not observed although deep-water saturations were slightly lower than during the August survey. The metalimnetic oxygen decrease was probably related to the decomposition of the current year's production of algae by bacterial oxidation, biological respiration and chemical oxidation. Uniform epilimnetic temperatures and dissolved oxygen saturations were present during the autumn survey.

pH, Total Alkalinity and Free Carbon Dioxide

The surface pH values in Weslemkoon Lake were near neutral, being consistent with soft-water Precambrian lakes. In the surface waters, the pH was usually higher than that of the bottom waters. For example, on July 8 at station 18, values at 1 and 35m were 7.5 and 6.9, respectively. Free carbon dioxide and total alkalinity concentrations were generally higher in the hypolimnion than in the warmer surface waters. Specifically, on August 28 free carbon dioxide concentrations at 1 and 13m (station 41) were 2.8 and 10.7 mg/l respectively.



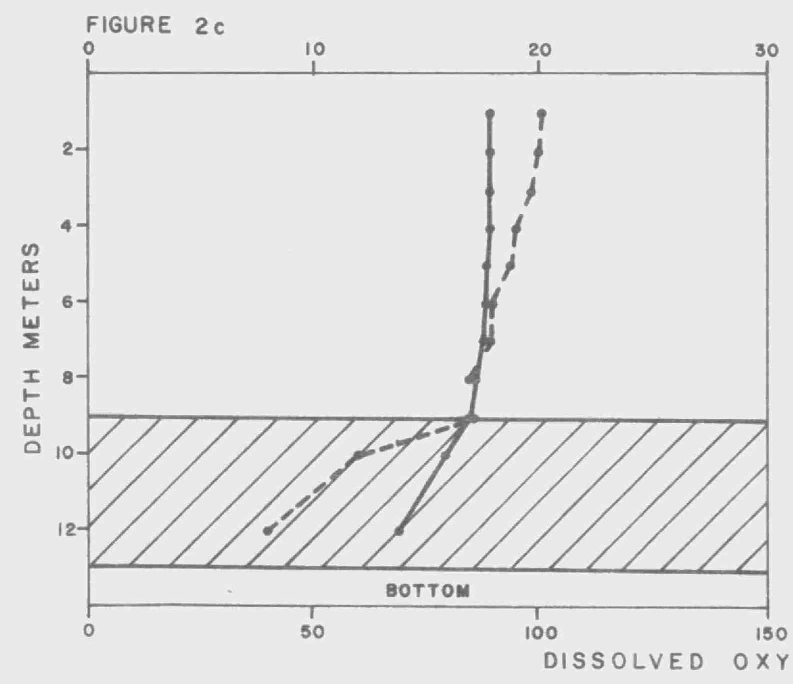


Figure 2: Temperature and dissolved oxygen profiles in Weslemkoon Lake, Station 41, (a) July 10, 1971 and (b) August 29, 1971 and (c) October 5, 1971. The shaded areas approximate the position of the thermocline.

——— Temperature

- - - - Dissolved Oxygen

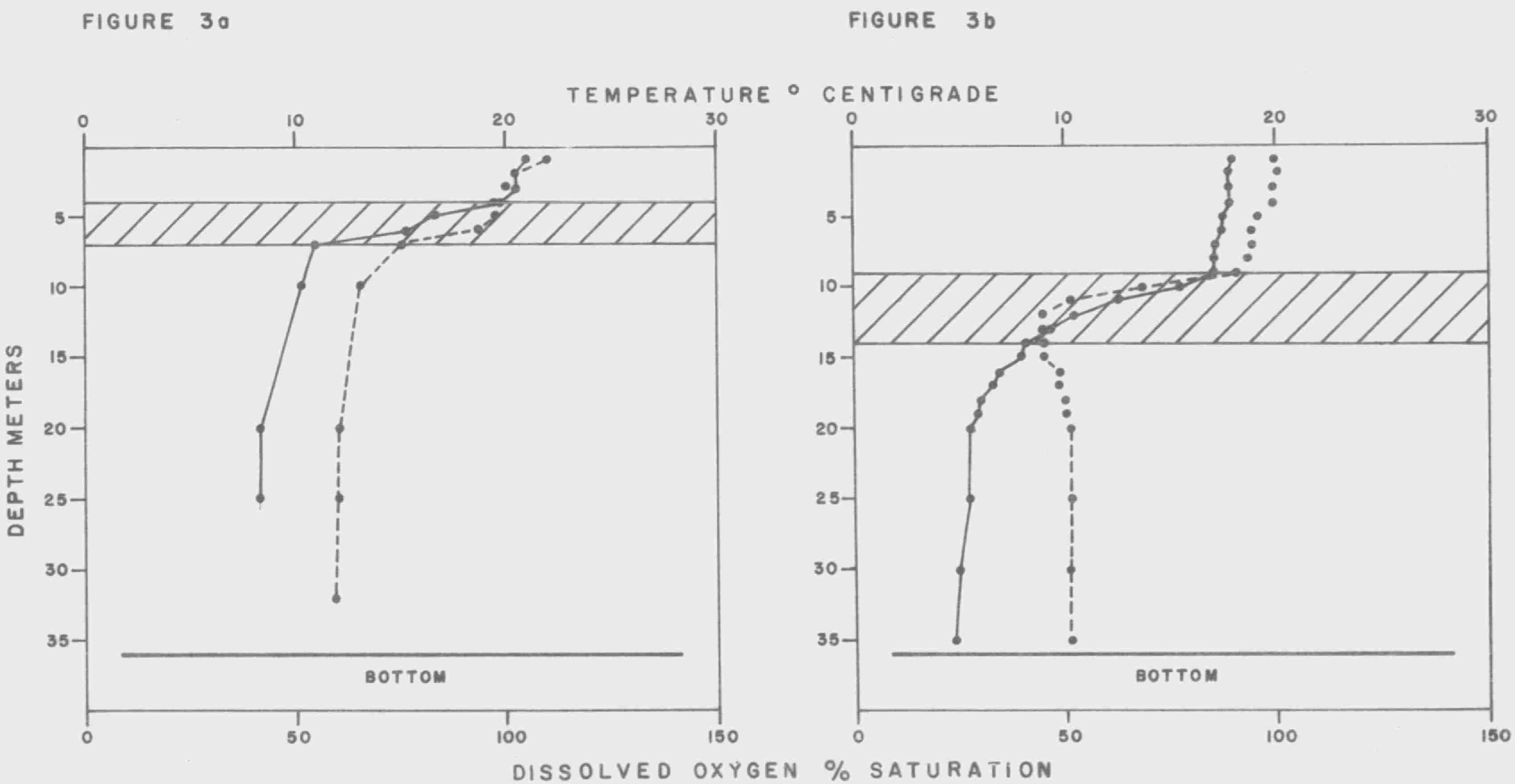


Figure 3: Temperature and dissolved oxygen profiles in Weslemkoon Lake, Station 18 for (a) July 10, 1971 and (b) October 3, 1971. The shaded areas approximate the position of the thermocline.

——————— Temperature

- - - - - - - - Dissolved Oxygen

Corresponding total alkalinity values were 5.7 and 8.3 mg/1. Reduced pH values in the bottom waters are due to the accumulation of carbon dioxide derived from organic decomposition while the increased alkalinity is related to the release of bicarbonate from sediments by bacterial and chemical action in conjunction with calcium, magnesium, iron, manganese and ammonia.

Hardness, Conductivity, Chloride and Iron

Surface hardness values for the mid-lake stations ranged from 18 to 26 mg/1, conductivities ranged from 45 to 51 μmhos/cm^3 and chloride concentrations were 1 or 2 mg/1. These values were characteristic of soft-water lakes and were consistent with each other indicating that no unusual mineral characteristics were present. Soaps will be effective in such soft water, therefore, the use of detergents containing phosphorus is unnecessary.

Water near the Fraser Creek inlet (Station 66) had a greater mineral content than the remainder of the lake with hardness values from 28 to 38 mg/1. Conductivities were from 77 to 88 μmhos/cm^3 and chloride concentrations were 5 mg/1.

Iron concentrations were low (0.05 to 0.15 mg/1) at all stations except 66 which had values from 0.30 to 0.55 mg/1.

Kjeldahl Nitrogen and Total Phosphorus

Surface concentrations of Kjeldahl nitrogen were low at the mid-lake stations (0.25 to 0.38 mg/1). Samples from inlet stations 66 and 67 had higher concentrations, from 0.44 to 0.67 mg/1 and from 0.38 to 0.52 mg/1, respectively. Bottom water samples collected at stations 18, 41, 58 and 59 in August had concentrations of 0.21, 0.84, 0.54 and 0.21 mg/1 respectively.

Surface concentrations of total phosphorus were from 0.11 to 0.22 mg/1 0.007 to 0.010 mg/1 and 0.004 to 0.010 mg/1 for the July, August and October surveys. The corresponding averages for 11 stations, excluding 66 and 67 were 0.015, 0.008 and 0.007 mg/1.

The concentrations at Station 66 were 0.032, 0.021 and 0.022 mg/l for the three surveys and the corresponding values at Station 67 were 0.019, 0.018 and 0.019 mg/l. The four hypolimnetic samples contained from 0.020 to 0.084 mg/l.

At Stations 41 and 58 the increased concentrations of both nitrogen and phosphorus in the hypolimnion do not correspond to low dissolved oxygen; therefore, they are likely due to organic matter settling out of the epilimnion rather than recycling from the sediments. High phosphorus concentrations in the hypolimnion are not common under oxic conditions and the exact implications of this observation are not known.

The weight ratios of nitrogen to phosphorus present an interesting picture. High ratios, in the range of 50, are characteristic of natural waters unaffected by waste inputs (Edmondson 1970). Domestic and other waste inputs tend to generate lower ratios and in very polluted waters, ratios may be less than 5. The average ratios for all five mid-lake stations were 23, 37 and 45 for the three surveys respectively. The corresponding averages for Stations 66 and 67 were 12, 21 and 29. It appears from these ratios that Weslemkoon Lake was being subjected to nutrient enrichment in spring which subsided over the summer. Fraser Creek was one source but seems unlikely to have affected the entire lake, since its influence was reduced even at Station 67 close to the inlet. It would appear that the higher level of nutrient, detected in July, may be the result of the flushing out of domestic wastewater leachate from the saturated shoreline soils during the spring snow-melt and subsequent wet weather periods.

Chlorophyll a

The chlorophyll a concentrations and Secchi-disc values from Stations 18, 41, 58 and 59 are presented in Table 1. Chlorophyll a concentrations were extremely low, ranging from 1.3 to 2.2 ug/l, 1.0 - 2.1 ug/l and 0.4 - 1.3 ug/l for the July, August and October surveys respectively. These values were generally below the lower analytical limit of the test and reflect the low productive capacity or oligotrophic status of the lake.

Water clarity, which is one of the more important parameters used in defining water quality, may be measured using a secchi disc. Figure 4 presents a chlorophyll a-Secchi disc relationship for a number of surface waters and clarifies the "trophic status" of Weslemkoon Lake in relation to numerous other well known recreational lakes in the Province (see Brown 1972 for derivation of chlorophyll a - Secchi disc relationship). With respect to Figure 4, Weslemkoon Lake is positioned between values observed for the oligotrophic lakes Superior and Huron and the more mesotrophic Lake Ontario and Eastern Basin of Lake Erie. The lake was well removed from the Bay of Quinte, Gravenhurst Bay and Riley Lake, three extremely enriched bodies of water.

Sediment Diatom Analysis

A good deal may be learned about the developmental history of a lake by studying the distribution and succession of diatoms in lake sediments. The frustules are well preserved under most limnological conditions and due to their specific gravity, sink to the bottom and remain in the sediments. Therefore, a sediment sample extracted from the upper one centimeter of a core sample contains diatoms representative of the recent trophic status of a lake.

Using a ratio of diatom groups, Araphidinae to Centrales (A/C), in lake sediments, Stockner (1971) postulated a technique which classifies the trophic status in a number of soft-water lakes in north-west Ontario and developed the following broad trophic distinctions for lakes:

Type	Ratio
Oligotrophic	0 - 1.0
Mesotrophic	1.0 - 2.0
Eutrophic	> 2.0

To classify Weslemkoon Lake, triplicate analyses on three sediment cores provided mean A/C ratios of 1.64, 1.76 and 1.55 for station 58 and 1.06, 0.96 and 0.98 for Station 59 (Table 2). The values for Station 58 indicate that planktonic diatom populations characteristic of mesotrophic lakes currently characterize the waters of the north end of Weslemkoon. In contrast, values for station 59 reflect the presence of a flora common to oligotrophic-mesotrophic waters.

FIGURE 4

CHLOROPHYLL a - SECCHI DISC RELATIONSHIP

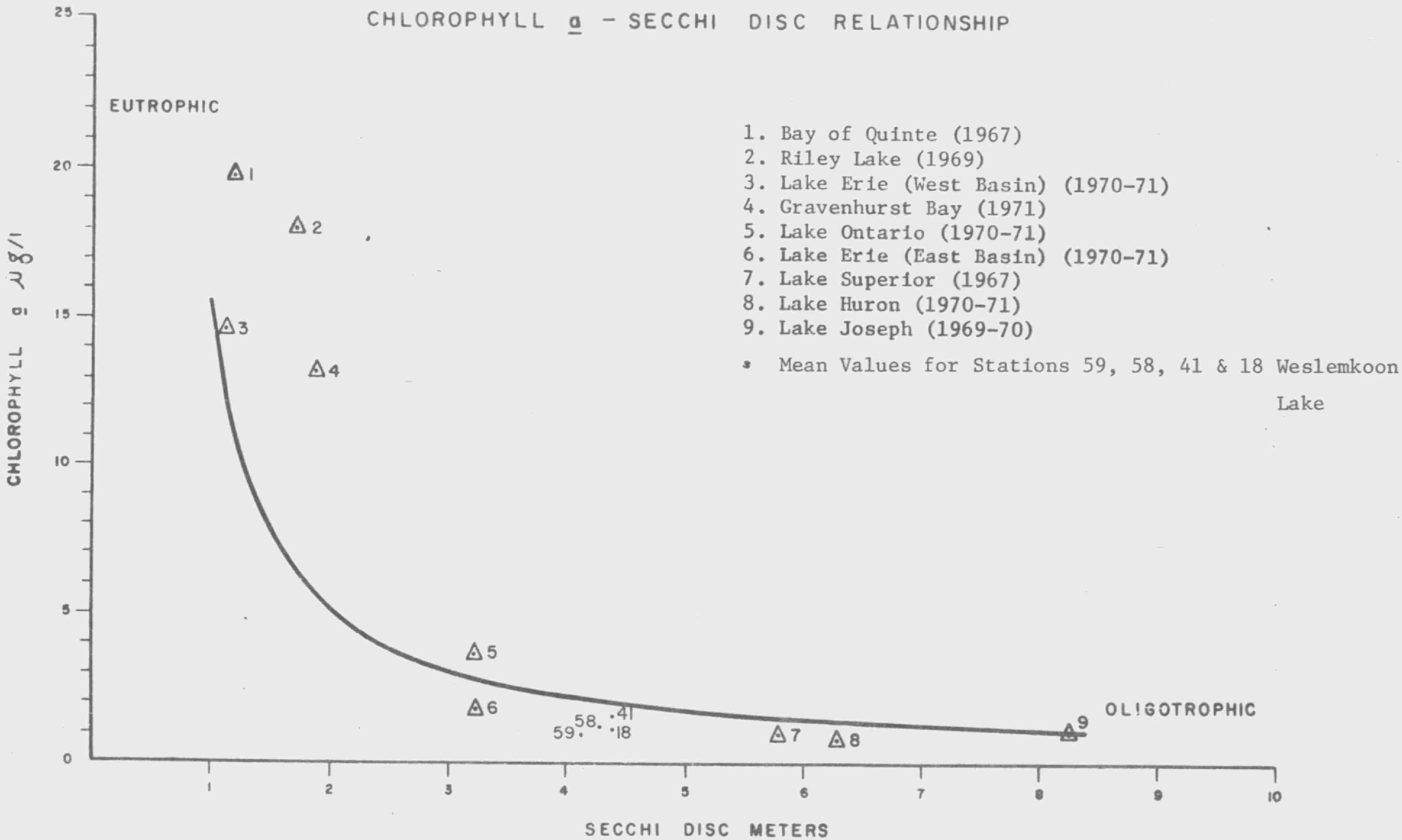


FIGURE 4: The relationship between chlorophyll a and Secchi disc as determined by the recreational lakes surveyed in 1971 as well as the mean chlorophyll a and Secchi disc values for Weslemkoon Lake. The Great Lakes values were added for comparative purposes.

Bacteriology

The concentrations of bacteria in Weslemkoon Lake fluctuated widely during the July survey, creating technical difficulties in counting. The bacterial levels on the first day (July 8) were quite high but increased drastically at most stations on July 9 and 10, then plunged to very low levels on July 11 and 12. The sudden increase in bacterial numbers caused the plates to be so crowded with colonies that in some cases accurate enumerations were impossible. In these cases, the bacterial concentrations were obviously far in excess of the acceptable levels for total body contact recreational use as specified in the OWRC criteria (OWRC, 1970). For example, approximate counts recorded on July 10 for station 21 were 40,000 TC/100 ml and 8,000 FC/100 ml. The FS plates were too crowded to enumerate. Geometric means could not be calculated when there were no numerical results, consequently the analysis of variance program was not used in the July survey. Instead, the stations were categorized according to the number of days that the FC counts exceeded 200/100 ml (Figure 5). The FC organisms are the most accurate of the indicators of fecal pollution and the 200 FC/100 ml limit was used instead of the OWRC geometric mean criterion of 100/100 ml because the counts were based on daily determinations.

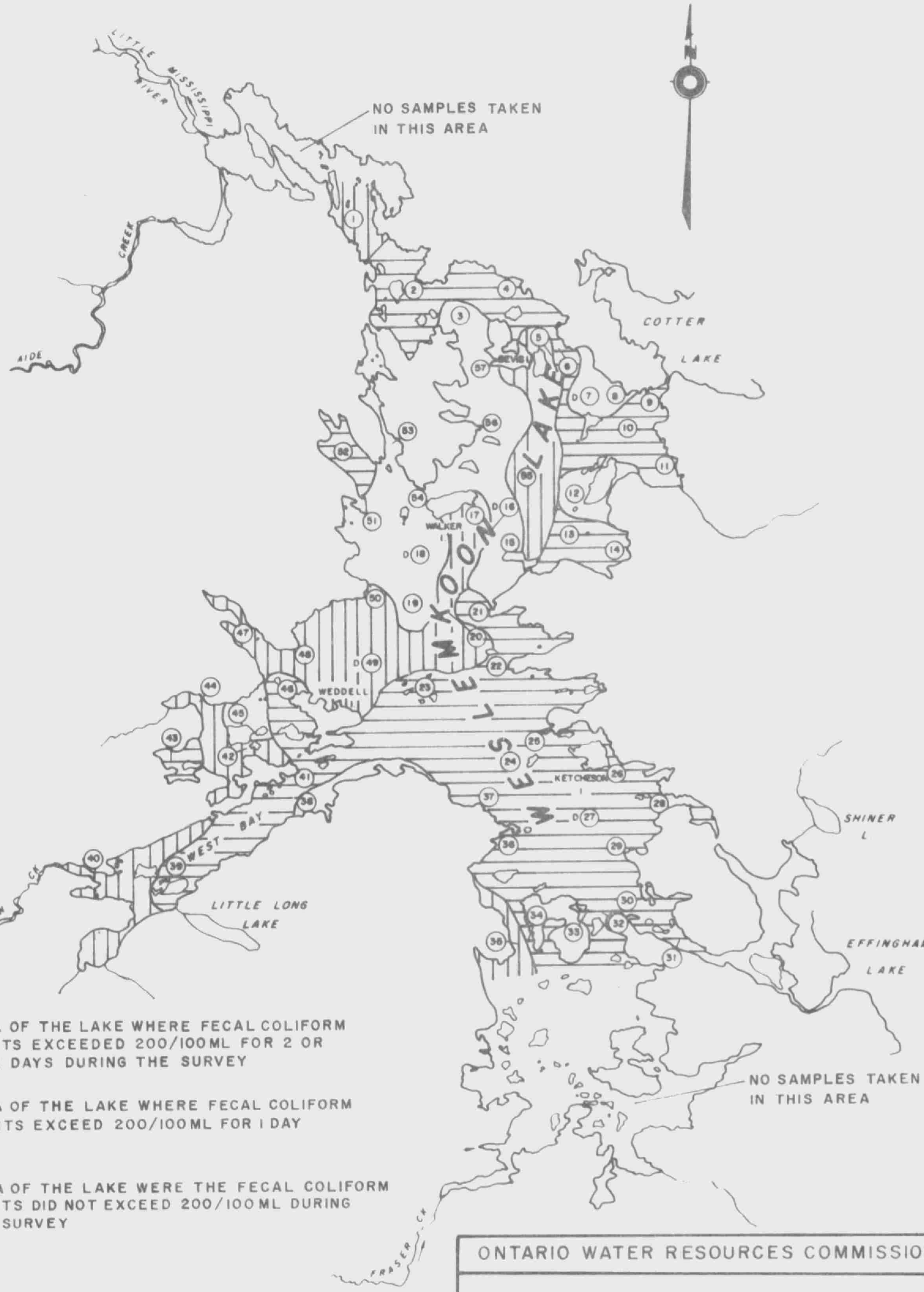
The great increases in bacterial numbers were subsequent to rainfall which was recorded at the climatological stations in Bancroft and Cloyne. Bacteria were carried into the lake at most stations immediately after the rain. However, by July 12, the bacterial levels had dropped to the extent that most stations were well within the OWRC criteria for recreational use (Table 3).

If the high FC counts, which have been attributed to the flushing action of runoff are correlated with rainfall, then the July 8 survey would be catching the residual contamination from the heavy rain on July 5 and 6. By July 8, the fecal coliforms had been dispersed throughout the lake and had died off to a great extent. The light rainfall on July 8 caused a second increase in FC counts on July 9. The FC counts remained high on July 10 but decreased greatly on July 11, and by July 12 only stations 26 exceeded 200/100 ml level.

WESLEMKOON LAKE

FIGURE

JULY SURVEY JULY 8-12, 1971



LEGEND

AREA OF THE LAKE WHERE FECAL COLIFORM COUNTS EXCEEDED 200/100ML FOR 2 OR MORE DAYS DURING THE SURVEY

AREA OF THE LAKE WHERE FECAL COLIFORM COUNTS EXCEED 200/100ML FOR 1 DAY

AREA OF THE LAKE WERE THE FECAL COLIFORM COUNTS DID NOT EXCEED 200/100ML DURING THE SURVEY

STATUTE MILES

1 1/2 0 1

ONTARIO WATER RESOURCES COMMISSION

RECREATIONAL LAKES PROGRAM

WESLEMKOON LAKE

1971 WATER QUALITY SURVEY

SCALE: AS SHOWN	
DRAWN BY: R.S.	DATE: FEBUARY 1972
CHECKED BY:	DRAWING Nº: 72-20-D.E.A

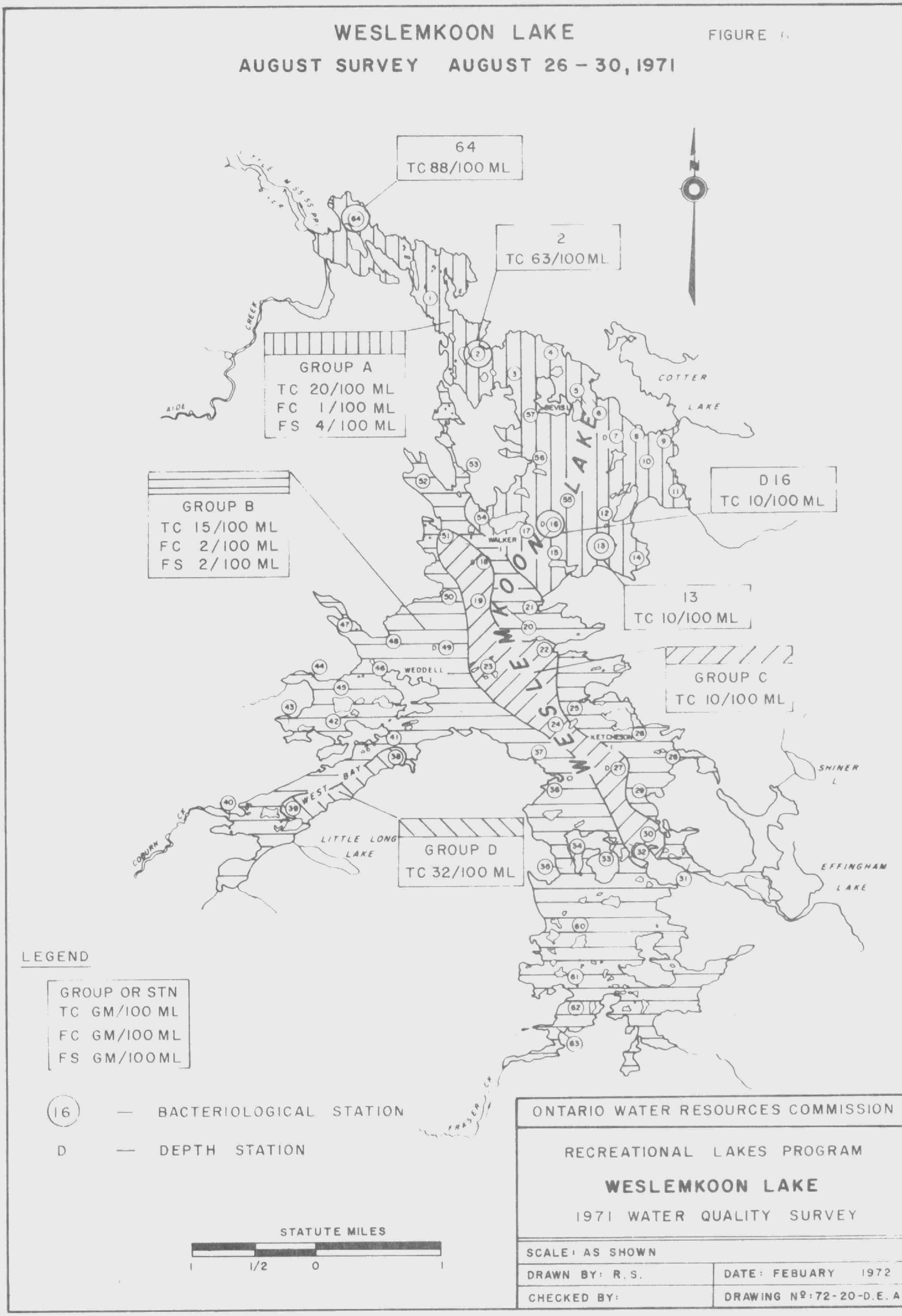
Although there appears to be a good correlation between developed areas and FC densities in the adjacent water (Figures 5 and 6), it is not possible to define the specific sources of contamination.

Rainfall occurred during the August survey but the bacterial levels remained both constant and low in contrast to the effects of rainfall in the July survey. If the soil, during the July survey, was saturated before the rain then runoff would readily occur with minimal precipitation. If the soil was dry during the August survey, the rain would have dissipated into the soil and not resulted in runoff. Soil moisture content was not determined during either survey. The meteorological data prior to the August survey indicated that the weather was generally sunny and hot.

Numerical counts were obtained for all samples during the August and October surveys which allowed the use of the ANOVA-CRE program.

In August, the lake was divided into four homogeneous groups (Tables 4, 5 & 6). The north section of the lake (Group A) had good bacteriological water quality of 20 TC/100 ml, 1 FC/100 ml and 4 FS/100 ml. In this group Stations 13 and D16 had slightly lower TC levels while Stations 2 and 64, near heavily cottaged areas, had slightly higher TC numbers (Figure 6). Group B, which extended along the shoreline of the southern section of the lake, had bacterial levels similar to Group A of 15 TC/100 ml, 2 FC/100 ml and 2 FS/100 ml. Group C, in the central section of the lake, had lower TC levels of 10/100 ml and Group D, adjacent to a heavily developed area on the southern shore of West Bay, had slightly higher TC levels than Group B.

The TC levels throughout the lake increased greatly by October. The reason for these high TC counts is not certain but if they had been due to fecal contamination, there would definitely have been a corresponding increase in FC counts. Although the TC groups are generally used to measure fecal pollution, there are also a number of bacteria indigenous to soil that are included in the TC group. The high TC counts encountered in this survey were probably soil types that gave a positive test.


WESLEMKOON LAKE
FIGURE 6
AUGUST SURVEY AUGUST 26 – 30, 1971
64
TC 88/100 ML
2
TC 63/100 ML
GROUP A
TC 20/100 ML
FC 1/100 ML
FS 4/100 ML
GROUP B
TC 15/100 ML
FC 2/100 ML
FS 2/100 ML
D 16
TC 10/100 ML
13
TC 10/100 ML
GROUP C
TC 10/100 ML
GROUP D
TC 32/100 ML
WESLEMKOON LAKE
CREEK
AIDE
COTTER LAKE
BEVIS I.
WALKER I.
WEDDELL I.
KETCHESON I.
WEST BAY
LITTLE LONG LAKE
SHINER L.
EFFINGHAM LAKE
COBURN CK.
FRASER CK.
LEGEND
GROUP OR STN
TC GM/100 ML
FC GM/100 ML
FS GM/100 ML
16 — BACTERIOLOGICAL STATION
D — DEPTH STATION
STATUTE MILES
1 1/2 0 1
ONTARIO WATER RESOURCES COMMISSION
RECREATIONAL LAKES PROGRAM
WESLEMKOON LAKE
1971 WATER QUALITY SURVEY
SCALE: AS SHOWN
DRAWN BY: R.S.
DATE: FEBUARY 1972
CHECKED BY:
DRAWING Nº: 72-20-D.E.A

Group E (Figure 7) which included most of Weslemkoon Lake had high TC levels (4,623/100 ml) while Groups F and G had lower TC levels of 3,266/100 ml and 397/100 ml respectively. Groups E, F & G had very low FC concentrations of 1/100 ml and low FS concentrations of 2/100 ml. Stations 40 and 44 on the west shore of the lake had higher FC levels of 7 and 9/100 ml respectively indicating a slight but significant bacterial input.

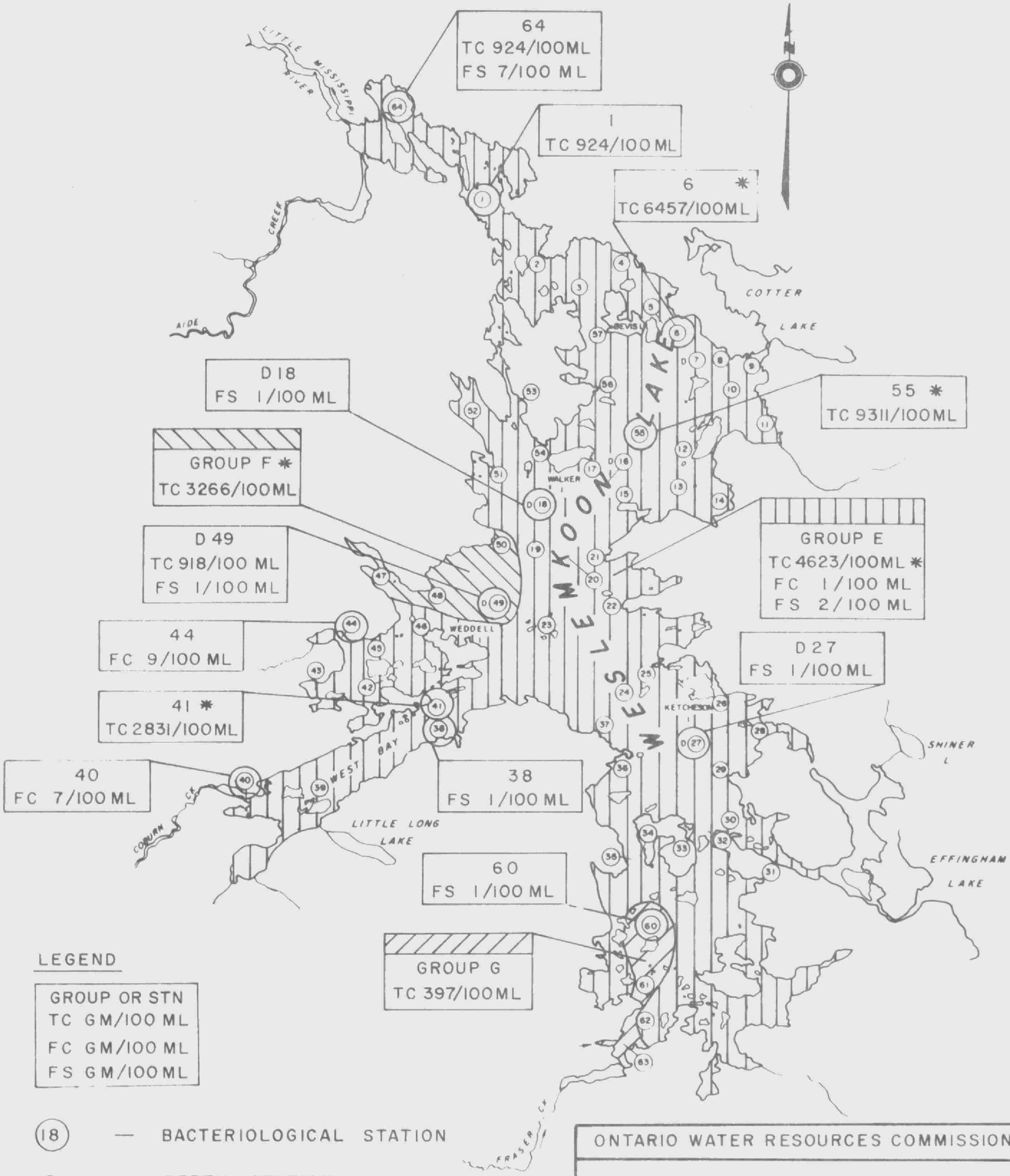
During the August and October surveys, Weslemkoon Lake had good bacterial water quality; however, the data from the July survey indicated a great deal of bacterial contamination was gaining access to the lake, during rainfalls, creating a short-term potential health hazard. It would appear that the existence of inadequate domestic waste disposal sytems, particularly in the more densely developed sections of the shoreline, was the source of bacteriological input.

Although no surface water is considered potable without prior treatment including disinfection, particular attention should be paid to any water used for drinking that is drawn from Weslemkoon Lake, especially after a rain.

WESLEMKOON LAKE

FIGURE

OCTOBER SURVEY OCTOBER 2-6, 1971



LEGEND

GROUP OR STN
TC GM/100 ML
FC GM/100 ML
FS GM/100 ML

(18) — BACTERIOLOGICAL STATION

D — DEPTH STATION

✱ — EXCEED OWRC CRITERIA FOR RECREATIONAL USE

STATUTE MILES

1 1/2 0 1

ONTARIO WATER RESOURCES COMMISSION

RECREATIONAL LAKES PROGRAM

WESLEMKOON LAKE

1971 WATER QUALITY SURVEY

SCALE: AS SHOWN	
DRAWN BY: R. S.	DATE: FEBUARY 1972
CHECKED BY:	DRAWING Nº: 72-20-D.E.A

TABLE 1 Chlorophyll a and Secchi disc values for Weslemkoon Lake during 1971.

DATE		Station 18		Station 41		Station 58		Station 59	
		Chloro a	S.D.	Chloro a	S.D.	Chloro a	S.D.	Chloro a	S.D.
July	8	1.8μg/l	3.0m	2.1μg/l	3.75m	1.8μg/l	2.8m	1.5μg/l	3.5m
"	9	1.3	4.0	2.0	3.75	1.4	4.0	1.8	4.3
"	10	1.6	3.7	1.5	4.2	1.8	3.5	1.4	4.5
"	11	1.8	4.0	2.2	4.0	1.8	3.3	1.6	3.5
"	12	1.5	3.8	1.8	4.2	1.8	4.0	1.4	3.5
August	26	1.1	5.0	1.4	5.0	1.6	5.0	1.0	4.9
"	27	1.4	5.0	1.3	5.0	1.4	5.0	1.5	5.0
"	28	1.6	5.0	1.5	4.7	1.4	4.9	1.5	5.0
"	29	2.1	4.8	1.4	4.5	1.4	4.7	1.8	4.7
"	30	1.2	4.6	1.2	5.5	1.3	5.5	1.2	5.0
October	2	1.1	4.5	0.7	4.0	0.6	4.5	0.6	4.0
"	3	0.5	4.5	1.1	4.0	0.6	4.5	0.4	4.5
"	4	0.8	4.5	0.8	4.5	0.5	4.5	1.0	4.7
"	5	0.8	4.5	0.9	4.4	0.6	4.6	0.9	4.5
"	6	1.1	4.7	1.3	4.5	1.0	4.4	0.7	4.3
MEAN		1.3	4.4	1.4	4.4	1.3	4.3	1.2	4.1

Chloro a = Chlorophyll a

S.D. = Secchi disc

μg/l = Micrograms/litre

m = Meters

TABLE 2: The Araphidinae/Centrales ratio of the surface sediment samples collected from Weslemkoon Lake, stations 58 and 59. The samples were collected in triplicate during the winter of 1971 and three separate analysis were performed on each core.

	CORE 1			CORE 2			CORE 3		
Station 58	A1	A2	A3	B1	B2	B3	C1	C2	C3
A/C Ratio	1.20	1.38	2.33	1.48	2.10	1.71	1.62	1.54	1.49
Mean A/C Ratio		1.639			1.763			1.550	
Station 59	A1	A2	A3	B1	B2	B3	C1	C2	C3
A/C Ratio	1.24	0.90	1.05	0.98	1.00	0.91	1.09	0.95	0.91
Mean A/C Ratio		1.065			0.963			0.985	

EXPLANATION OF TERMS IN BACTERIOLOGICAL TABLES

F	-	the calculated analysis of variance statistic on F ratio.
df	-	degrees of freedom of the F ratio for "between group" and "within group" variation.
F(5%)	-	the F ratio from a statistics table (Rohlf 1969). If the calculated F is greater than the F(5%), a significant difference (SD) occurred between the groups in the analysis. If the F is less than F(5%), no significant difference (NSD) occurred.
log GM	-	the logarithm (base 10) of the geometric mean.
S.E.	-	the standard error of the log GM where

$$S.E. = \frac{s}{\sqrt{n}} \quad \text{and } s = \text{standard deviation}$$

N	-	the number of values in the mean.
GM	-	the geometric mean of the bacterial level.
t	-	the calculated test of significance or student t-test used to compare stations, groups and a survey.

If t for the number of degrees of freedom shown is greater than the critical t value, a significant difference (SD) occurs.

SD refers to a significant difference at the .05 level but no significant difference at the .01 level.

SD* refers to a significant difference at the .01 level but no significant difference at the .001 level.

SD** refers to a significant difference at the .001 level.

TABLE 3

Summary of the Stations Which Exceeded 200 FC/100 ml During the July Survey.

Legend: X > 200 FC/100 ml

* > 100 FC/100 ml but <200 FC/100 ml

Station Number	July 8	9	10	11	12
1	*	X			
2	X	X			
3					
4	X	X			
5	*	X			
6		X			
7	*		*		
8					
9	X	X			
10	X	X			
11	*	X		X	
12	*				
13	X	X			
14	X	X			
15					
16					
17	X				
18			X		
19					
20			X		
21		X	X		
22		X	X		
23	X	X	X		
24	X	X	X		
25		X	X		
26		X		X	X
27	X		X		
28			X	X	
29		X	X		
30	X		X	X	

TABLE 3 - continued

Station Number	8	9	10	11	12
31		X		X	
32	X	*	X		
33		X		X	
34	X			X	
35			X		
36			X	X	
37			X	X	
38					
39			X	X	
40			X		
41			X	X	
42				X	
43		X	X	X	
44			X		
45					
46			X	X	
47				X	
48				X	
49	X				
50				X	
51					
52	X			X	
53					
54					
55		X			
56					
57					

TABLE 4a: Analysis of Variance Summary of Groups for Total Coliforms per 100 ml.

GROUP	August Survey GROUP A	October Survey GROUP E
	#1-12, 14-17, 54-57, 7D	All Stations Except 60, 63, 61, 47-50, 1, 64, 6, 14, 40, 41, 49D,55
F	1.27	1.518
df	19 , 20	32 , 130
F (.05)	1.54	1.55
	NSD	NSD
Log GM	1.311	3.665
SE	.036	.019
N	100	163
GM	20	4623

TABLE 4b:

	GROUP B	GROUP F
	#20,21,25-31,33-37, 40-49,50-53,62 and 63	Stations 47 to 50
F	0.560	0.278
df	28 , 116	3 , 15
F (.05)	1.55	3.24
	NSD	NSD
Log GM	1.186	3.514
SE	.021	0.214
N	145	19
GM	15	3,266

TABLE 4c:	GROUP C	GROUP G
	#18,18D,19, 22-24, 27D	Stations 60, 61,63
F	0.494	3.111
df	9 , 40	2, 12
F(.05)	2.12	3.89
	NSD	NSD
Log GM	1.000	2.599
SE	.000	0.012
N	50	15
GM	10	397

Table 4d: The Student-t test - Summary of Groups for Total Coliforms/100 ml

	August Survey
GROUP	GROUP D (Stations 38 & 39)
t	.018
df	8
t(.05)	2.306
log GM	1.5025
SE	.2222
N	10
GM	32

TABLE 5a: Analysis of Variance Summary of Groups for Fecal Coliforms per 100 ml

	August Survey	October Survey
GROUP	GROUP A	GROUP E
	Stations 1 - 17, 54 - 57, 64, 7D and 16D	All Stations except 40, 44
F	1.061	1.13
df	23 , 96	45 , 182
F (.05)	1.647	1.50
	NSD	NSD
Log GM	.1137	.069
SE	.0261	.010
N	120	228
GM	1	1

TABLE 5b:

GROUP	GROUP B
	#18-53,18D,127D, 49D,60-63
F	1.187
df	42 , 172
F(.05)	1.427
	NSD
Log GM	.1754
S.E.	.0245
N	215
GM	2

TABLE 6a: Analysis of Variance Summary of Groups for Fecal Streptococcus per 100 ml

	August Survey	October Survey
GROUP	GROUP A	GROUP E
	Stations: 1-17, 7D, 16D, 54 - 57, 64	All Stations except 18D, 27D, 38, 49D, 60, 64
F	1.506	1.270
df	23 , 96	41 , 167
F(.05)	1.647	1.50
	NSD	NSD
Log GM	.5597	.2824
SE	.0547	.0268
N	120	209
GM	4	2

TABLE 6(b):

	August Survey
GROUP	GROUP B
	Stations: 18-53, 18D, 27D, 49D, 60-63
F	0.728
df	42 , 172
F(.05)	1.472
	NSD
Log GM	.2555
SE	.0208
N	215
GM	2

GLOSSARY OF TERMS

ALKALINITY	:The alkalinity of a water sample is a measure of its capacity to neutralize acids. This capacity is due to carbonate, bicarbonate and hydrozide ions and is arbitrarily expressed as if all of the neutralizing capacity was due to calcium carbonate alone.
ANOXIC	:Refers to conditions when no oxygen is present.
BACKGROUND COLONIES	:Background colonies are other lake water bacteria capable of growing on the total coliform plate, in spite of the inherent restrictive conditions.
CHLORIDE	:Chloride is simply a measure of the chloride ion concentration and is not a measure of chlorination.
CHLOROPHYLL a	:A green pigment in plants.
CONDUCTIVITY	:Conductivity is a measure of the waters ability to conduct an electric current and is due to the presence of dissolved salts.
DIATOMS	:Unicellulr plants found on all continents and in all types of water where light and nutrients are sufficient to support photosynthesis. They are comprised of two siliceous frustules (cell walls) which have an outer valve (epitheca) fitting over the inner valve (hypotheca) like the lid on a box. The siliceous deposits comprising the frustules vary in regular patterns according to the individual species.
EPILIMNION	:Is the thermally uniform layer of a lake lying above the thermocline. Diagram I.
EUPHOTIC ZONE	:The lighted region that extends vertically from the water surface to the level at which photosynthesis fails to occur due to insufficient light penetration.
EUTROPHIC	:Waters containing advanced nutrient enrichment and characterized by a high rate of organic production.

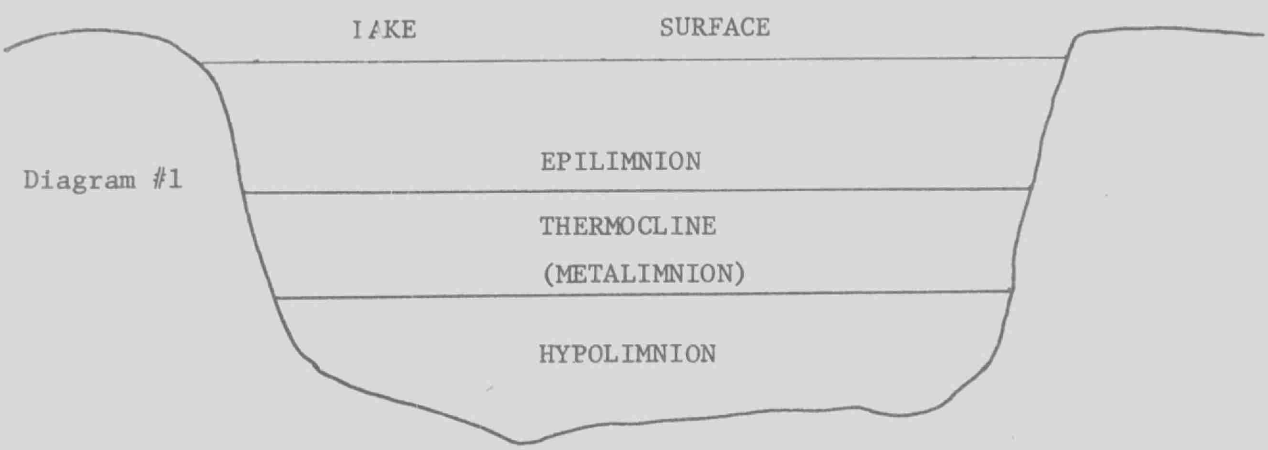
EUTROPHICATION	:The process of becoming increasingly enriched in nutrients. It refers to the entire complex of changes which accompanies increasing nutrient enrichment. The result is the increased production of dense biological growths such as algae and aquatic weeds which generally degrade water quality and render the lake unsuitable for many recreational activities.
FECAL COLIFORMS (FC)	:Fecal coliforms are bacteria associated with recent fecal pollution from man and animals.
FECAL STREPTOCOCCUS (FS)	:Fecal streptococcus are bacteria associated with fecal pollution from animals and to a lesser extent man.
HARDNESS	:Hardness of water is a measure of the total concentration of calcium and magnesium ions expressed as if all of the ions were calcium carbonate.
HYPOLIMNION	:The uniformly cold and deep layer of a lake lying below the thermocline, when the lake is thermally stratified. Diagram #1
KJELDAHL NITROGEN	:Sum of nitrogen present in the ammonia and organic forms (it does not include nitrite or nitrate).
MESTROPHIC	:Waters characterized by a moderate nutrient supply and organic production (i.e. midway between eutrophic and oligotrophic).
METALIMNION	:See thermocline.
OLIGOTROPHIC	:Waters containing a small nutrient supply and consequently characterized by a low rate of organic production.
pH	:Is the measure of the hydrogen ion concentration expressed as the negative logarithm of the molar concentration.
PHOSPHORUS (TOTAL)	:Sum of all forms of phosphorus present in the sample.

SECCHI DISC :A circular metal plate, 20 centimeters in diameter, the upper surface of which is divided into four equal quadrants. Two quadrants directly opposite each other are painted black and the intervening ones white. The secchi disc is used to estimate the turbidity of the lake water.

THERMAL STRATIFICATION :During the spring, vertical temperatures in a lake are homogeneous from top to bottom. As summer advances, the surface waters become warmer and less dense than the underlying cooler waters. A strong thermal gradient (Thermocline) occurs giving rise to three distinct water layers. The variation in density between layers retards mixing by wind action and water currents. Diagram #1.

THERMOCLINE (metalimnion) :The layer of water located between the epilimnion and hypolimnion in which the temperature exhibits a decline equal to or exceeding 1°C increase per meter.

Diagram #1



TOTAL COLIFORMS (TC) :Total coliforms are bacteria commonly associated with fecal pollution but may also be present naturally in the environment.

TROPHIC STATUS :Depending upon the degree of nutrient enrichment and resulting biological productivity, lakes are classified into three intergrading types:

TROPHIC STATUS (continued)

:oligotrophic, mesotrophic and eutrophic. If the supply of nutrients to an oligotrophic lake is progressively increased, the lake will become more mesotrophic in character and with continued enrichment it will become eutrophic.

BIBLIOGRAPHY

BENNETT, E.A. Taken from the Great Lakes as an Environment, Edited by D.V. Anderson, Great Lakes Institute Report PR 39, University of Toronto, October 1969

BROWN, D.J. 1972 Chlorophyll a - Secchi disc relationship in Ontario Recreational Lakes (In Preparation).

BURGER, A. Statistical Bacterial Data Summarization and Interpretation Internal OWRC Report (Unpublished).

EDMONDSON, W.R. 1970 Phosphorus, Nitrogen and Algae in Lake Washington after Diversion of Sewage. Science 169 No. 3946 : 690-691.

Guidelines and Criteria for Water Quality Management in Ontario, OWRC, June 1970.

Microbiological Criteria
Water used for body contact recreational activities should be free from pathogens including any bacteria, fungi or viruses that may produce enteric disorders or eye, ear, nose, throat and skin infections. Where ingestion is probable, recreational waters can be considered impaired when the coliform, fecal coliform, and/or enterococcus geometric mean density exceeds 1000, 100 and/or 20 per 100 ml respectively, in a series of at least ten samples per month, including samples collected during weekend periods.

RICHARDS, F.A. and THOMPSON, T.G. 1952 The estimation and characterization of plankton populations by pigment analysis II. The spectrophotometric method for the estimation of plankton pigments. J. Marine Res., 11:156.

ROHLF, F.M. and SOKAL, R.R., 1969 Statistical Tables, W.H. Freeman and Company, San Francisco.

SOKAL, R.R. and ROHLF, F.J. 1969 Biometry, the principals and practices of statistics in biological research, W.H. Freeman and Company, San Francisco.

Standard Methods for the Examination of Water and Wastewater, 13th Edition, 1971. APHA, AWWA, WPCF.

STOCKNER, J.G. 1971 Preliminary characterization of lakes in the Experimental Lakes Area, Northwestern Ontario, using diatom occurrences in sediments. J. Fish. Res. Bd. Canada 28:265-275.